Conclusion

This system was used for prognosing the inflation index on 1. 01. 2005, the system was used in July, 2005, the inflation index obtained was equal 12.8%, the prognosed estimates of the official institutes and external experts were fluctuating between 8% to 20% and plus. The official statistic data of the ministry of Economy of Ukraine come up to 10,5% and the Institute for Economics and Prognosing suggested 12,5% - 13%. Taking into consideration the level of irregular economy the second figure seems much more realistic.

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SYNERGETIC METHODS OF COMPLEXATION IN DECISION MAKING PROBLEMS

Albert Voronin, Yury Mikheev

Abstract. Synergetic methods of data complexation are proposed that make it possible to obtain a maximal amount of available information using a limited number of channels. Along with freedom degrees reducers, a mechanism of freedom degrees discriminators is proposed that enables all the channels to take part in the development of a cooperative decision in accordance with their informativeness in a current situation.

Keywords: Synergetics, data complexation, information channels, decision making

Introduction

In advanced information systems, information on the same object (a process or an event) is usually transmitted over *several* channels. The problem lies in determining the channels over which more significant data are transmitted. Depending on this, it is required to combine (integrate) obtained data to develop a cooperative decision on the state of an object.

Taking into account a role of information accuracy in constructing the present-day decision-making systems the problem considered in this article should be regarded as topical.

Analysis of the problem state

The synergetic conception of data complexation is actively applied to the extraction of a maximum of useful information from an available collection of the various data that characterize a process or an object in various application domains.

As an example we shall cite a problem of the height of a plane estimation using indications on barometric, onboard and ground radar-tracking gadgets and, probably, on the visual channel. Each of the specified channels has its advantages and lacks in various flight conditions. It is required to combine (integrate) the obtained data for the most authentic height estimation in a current situation.

In the monograph [1], the problem of integration of the devices having different accuracy class indications is considered. Each of the devices brings its mite in the resulting indication according to its accuracy class. Also, the problem of integration of experts estimates here is put and solved in view of the different experts competence in a case in point.

In paper [2], an automatic classification method of the state of forests is described that is based on a satellite data map and the synergetic merging of data principle. The most informative (dominant) spectral channels of the sensor being used are detected, and the sought-for decision is taken upon their evidences.

In [3], the problem of integration of signals from navigating fields of different physical natures (radio-navigation fields such as GPS, geophysical fields, the field of stars and bodies of Solar system, etc.) is formulated for the most authentic estimation of the current coordinates of a space vehicle.

In [4], a method of complexation of signals for bi-static radar-location of small celestial bodies is described. To increase the accuracy of measurements in investigating parameters of motion of small celestial bodies, a bi-static configuration of radar-tracking systems is used. Data from each of the receiving antennas spaced on sizable distances are processed and compared among themselves so that the resulting signal is most reliable.

In the given examples, the concept of synergetics [5,6] – the science about cooperative processes is used. In the hierarchy of systems theories, synergetics occupies the upper level. As against the general systems theory, synergetics studies and organizes the processes running not under centralized actions but due to collective components interaction according to the result in view. The cooperation of components makes it possible to use reserve capabilities of a system and substantially increases the system effect degree.

By the definition of P.K. Anokhin, "we can call a system only such a complex of selectively involved components that their interaction and interrelation assume the character of *mutual assistance* of components that is oriented toward a fixed useful result" [7]. The stated fundamental property of mutual assistance is a synergetic process that is clearly expressed and everywhere manifests itself in biological systems [5].

During the synthesis of a synergetic functional system, redundant freedom degrees (Ashby law [8] about a requisite variety), should first be created that determine additional capabilities in the properties of the future system, and then they are reduced according to the dominant mechanism during the functioning of the system [5]. To achieve this end, “reducers of freedom degrees” are introduced into the system being synthesized with the help of a special control law.

Synergetic concept of complexation (confluence) of the data is actively applied to extraction of the maximal information from available set of the various data not only in biology, but also in other object domains to what the given examples testify.

Substantial analysis of the problem

In contrast to biological and similar synergetic control systems, the complexation systems do not contain, as a rule, redundant channels of data gathering. The number of freedom degrees is a priori limited, and the heart of the problem consists of obtaining a maximum amount of available information under these constraints. There exist two approaches to the problem. In the above examples, the action of "reducers of freedom degrees" has led to the truncation of low-informative channels and to the selection of one or several most informative (dominant) in the current situation data acquisition channels on the basis of which the sought-for decision has been formed.

In applying this approach, some useful nuances contained in the truncate channels do not participate in the process of searching for the decision, i.e. some information items are lost. Figuratively speaking, one or several dominant “soloists" whose sounding does not contain the overtones that attach particular significance to a musical performance are artificially selected from the entire ensemble of data.

At the second approach, it is advisable to abandon the conception of a dominant and, instead of "reducers of freedom degrees" to include mechanisms that allow all channels of data acquisition to participate in the formation of the sought-for decision with weights corresponding to their informativeness degree in the current situation ("discriminators of freedom degrees”). As a result, all the available information items will be properly used and the "sounding" of the data ensemble will be harmonious and volumetric. Both approaches have their pluses and minuses and both are applied in practice.

Statement of the problem

It is given: quantity of data channels (number of freedom degrees in synergetic complexation system) $m \geq 3$. The array of initial data is represented in the form of the column matrix

$$A^T = \| \alpha_1 \ \alpha_2 \ ... \ \alpha_m \ \|, \tag{1}$$

where $\alpha_j, j \in [1, m]$ – the data on some numerical value a, received on j-th channels (components of the complexation system).

It is required to determine the most authentic estimation a^* of the value a.

Method of solution

If the number of channels is great enough and it is known, that their self-descriptiveness degrees are approximately identical, the problem is solved by simple averaging channels data as the maximum likelihood estimator:

$$\alpha^* = \frac{1}{m} \sum_{j=1}^{m} \alpha_j \ .$$

The need for increase of estimation reliability arises, when the number of data channels is small, and the relative degree of trust to them is different and not known beforehand. Hereinafter we shall apply, for example, the first approach to the complexation problem.

In this case, for the solution of a problem in view we shall take advantage of the “freedom degrees reducers” mechanism. The iterative synergetic process of adaptive mutual assistance of system components is organized.

Since the channel that deserves to be more believed is not yet known, we first assume that the degree of belief to all the channels data is the same and, in averaging them, their data are taken with one coefficient $k_j^I = 1, \ j \in [1, m]$.

As a result of averaging, the following mean estimate is obtained:

$$\alpha^I = \frac{1}{m} \sum_{j=1}^{m} k_j^I \alpha_j = \frac{1}{m} \sum_{j=1}^{m} 1 \cdot \alpha_j = \frac{1}{m} \sum_{j=1}^{m} \alpha_j .$$

We call it the estimate of the first iteration. The operation of averaging in matrix form is the multiplication of the matrix - column of the data from the left by a unit m-row matrix (summing vector)

$$E = \begin{Vmatrix} 1 & 1 & \dots & 1 \end{Vmatrix}$$

and division of the product obtained by the channels number :

$$\alpha^{I} = \frac{1}{m} EA.$$

We now have information on the mean estimate α^{I} and can compare it with estimates of each channel α_j from matrix (1). Of course, the difference between the mean estimate (the opinion of the majority) and the estimate proposed by a channel can form the basis for the change in the weight coefficient with which the "opinion" of the channel is taken into account. For those channels, whose estimates on the first iteration are closer to the mean estimate, it is expedient to increase the coefficient k_j, and, on the contrary, this coefficient should be decreased for the channels whose estimates are far different from the mean estimate. In our procedure, the relatively rare cases when the opinion of the minority is "true" are omitted.

Let us introduce the following measure (the "reducers of freedom degrees")

$$\delta_j^{II} = \left| \alpha^{I} - \alpha_j \right|, j \in [1, m],$$

that is the quantitative representation of the trust degree of the *j*-th channel at the second iteration. It make sense to select coefficients k_j^{II} such that they would be functions inversely proportional to δ_j^{II} :

$$k_j^{II} = c / \delta_j^{II}, \ c = \text{const}, \tag{2}$$

under the condition

$$\sum_{j=1}^{m} k_j^{II} = m. \tag{3}$$

Solving the system of equations (2) and (3), we eliminate the unknown coefficient of proportionality c and obtain

$$k_j^{II} = \left(\frac{m}{\delta_j^{II}}\right) / \sum_{t=1}^{m} \left(\frac{1}{\delta_t^{II}}\right).$$

Then we perform the averaging operation at the second iteration but, in this case, take into account the different trust to channels according to the results of the first iteration,

$$\alpha^{II} = \frac{1}{m} \sum_{j=1}^{m} k_j^{II} \alpha_j. \tag{4}$$

Introducing a row matrix

$$K^{II} = \begin{Vmatrix} k_1^{II} & k_2^{II} & \dots & k_j^{II} & \dots & k_m^{II} \end{Vmatrix},$$

we represent expression (4) in matrix form

$$a^{II} = \frac{1}{m} K^{II} A.$$

At the third iteration, the measure

$$\delta^{III} = \left|\alpha^{II} - \alpha_j\right|, j \in [1, m],$$

is first established and so on.

The iterative procedure

$$a^{(g)} = \frac{1}{m} K^{(g)} A, g \in [1, h], K^1 = E$$

continues until the condition of termination

$$\left|\alpha^{(h)} - \alpha^{(h-1)}\right| \leq \varphi$$

is false, where φ is a given small quantity. The result of the iterative procedure described is the obtaining of a refined estimate $a^* = a^{(h)}$ determined with due regard for the heterogeneity of channels. In practical cases, the iterative process converges after 3-4 iterations and the most informative channel is determined.

Synergetic aspects of mathematical statistics

The synergetic principle of data complexation has much in common with ideas of mathematical statistics [9]. Really, when the synergetic conception of data merging is applied to the most authentic estimation of characteristics of processes (objects) from an available data set, then the mathematical statistics studies methods for the most authentic estimation of moments of distribution of random quantities from an available set of sample units. The commonality of problems of both theories testifies to the topicality of the problem of investigating synergetic aspects of mathematical statistics both for synergetics, and also for the development of statistical methods. In order to illustrate the second approach, here we shall provide the mechanism of "discriminators of freedom degrees" for the problem solving.

Let us consider a problem of the information processing at the limited number of data channels as calculation of the best (in a sense) estimate θ^* of the unknown distribution parameter θ of the random quantity X with probability density $f(x|\theta)$ on the basis of a limited statistical material $x = x^{(n)} = (x_1, x_2, ..., x_n)$ – analogue of freedom degrees of a data integration synergetic system.

An efficient instrument of increasing the efficiency of statistical estimation is the Bayesian approach [9]. The aprioristic information that the unbiased estimate of parameter θ, assumed as the random quantity, is distributed under the same law as *X* is used. Minimization of the risk function for the square-law loss function gives the expression for an optimum estimate as the posteriori mathematical expectation of parameter θ, calculated on to the given vector of observations:

$$\theta^* = \int_{-\infty}^{+\infty} \theta f(\theta|x) d\theta \Big|_{x = x^{(n)}}. \quad (5)$$

Let us make use of the posteriori density definition under Bayes theorem [9]:

$$f(\theta|x) = \frac{f(x|\theta) f_a(\theta)}{f(x)},$$

where the normalizing marginal distribution is expressed by the formula

$$f(x)=\int_{-\infty}^{+\infty} f(x|\theta) f_a(\theta) d\theta.$$

Then expression (5) will be transformed to a kind

$$\theta^* = \left. \frac{\int_{-\infty}^{+\infty} \theta f(\theta|x) f_a(\theta|\theta') d\theta}{\int_{-\infty}^{+\infty} f(\theta|x) f_a(\theta|\theta') d\theta} \right|_{\bar{x}=\bar{x}(n)}, \tag{6}$$

where θ' – an unknown constant. Since the sought-for estimate must be computed from a given vector of observations, we should pass in expression (6) from integrals to summation over the elements of this sample and replace unknown constants by their estimates:

$$\theta^* = \frac{\sum_{i=1}^{n} x_i f(x_i|\theta^*) f_a(x_i|\theta^*)}{\sum_{i=1}^{n} f(x_i|\theta^*) f_a(x_i|\theta^*)}. \tag{7}$$

Formula (7) expresses dependence of the quantity θ^* on itself,

$$\theta^* = \varphi(x_1, x_2, ..., x_n; \theta^*),$$

As is well known [10], the equation in such a form can be solved by an iterative method. The iterative procedure is organized according to the recurrent formula

$$\theta^*[l] = \varphi(x_1, x_2, ..., x_n; \theta^*[l-1]), l \in [1, L],$$

and iterative process terminates when the condition

$$\theta^*[L] - \theta^*[L-1] \le \lambda_\theta$$

becomes true, where l - number of the current iteration and L is the number of iterations; λ_θ – a preassigned accuracy of computation of the sought-for estimate. If the questions of convergence should be analyzed, then we can use the well-known theorem [10] according to which, to provide convergence of the iterative process, it is sufficient that the following inequality be true in the considered interval of refinement of the estimate θ^*:

$$|d\varphi(x_1, x_2, ..., x_n; \theta^*) / d\theta^*| < 1.$$

The general expression for refined estimate (7) fully complies with the following idea of Gauss [11]. Most probable is such a value of parameter being estimated that minimizes the sum of squares of differences between the actually observable and computed values multiplied by the weight coefficient k_i that reflects the relative confidence in observations:

$$\theta^* = \arg\min_{\theta^*} \sum_{i=1}^{n} k_i (x_i - \theta^*)^2. \quad (8)$$

In [12,13], it is shown, that expression (7) really is obtained from (8) if the posteriori probability density ("discriminators of freedom degrees") is introduced in the capacity of the measure of relative confidence in observations.

Thus, the methodology proposed provides the individual approach to each realization of a random quantity (weighing in accordance with the posteriori probability of its occurrence), which makes it possible [14] to avoid the information loss in computing the sought-for estimates from a small sample.

It is important to note that an estimate is elaborated by means of the organization of an iterative process in which sample units adaptively interact among themselves during each iteration. Similarly, synergetics provides a process characterized by self-control and self-organization according to the objective formulated. Adaptable processes are developed owing to the collective interaction of components. The cooperation of components activates reserve capabilities of a system and considerably increases the extant of system effect.

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